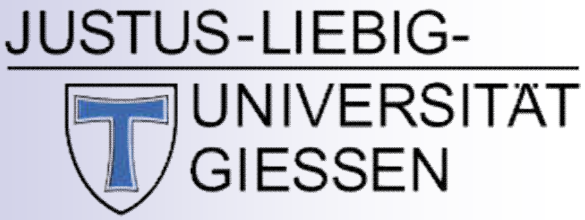
CLAS collaboration meeting, JLAB

November 11, 2020

N→N* transition GPD measurements with CLAS12 at JLAB



Stefan Diehl

for the CLAS collaboration

Justus Liebig University Giessen

University of Connecticut

Physics Motivation

3D structure of the ground state nucleon: Classical GPDs

➔ Measured with processes like DVCS, DVMP, …

3D structure of excited nucleon states: transition GPDs

8 twist-2 GPDs:

unpolarized:

$$\int_{-1}^{1} dx H_M(x;\xi;t) = 2G_M^*(t)$$

$$\int_{-1}^{1} dx H_E(x;\xi;t) = 2G_E^*(t)$$

$$\int_{-1}^{1} dx H_C(x;\xi;t) = 2G_C^*(t)$$

$$\int_{-1}^{1} dx H_4(x;\xi;t) = 0$$

Jones-Scardon EM FF for the N → transition

polarized:

$$\int_{-1}^{1} dx C_1(x;\xi;t) = 2C_5^A(t)$$

$$\int_{-1}^{1} dx C_2(x;\xi;t) = 2C_6^A(t)$$

$$\int_{-1}^{1} dx C_3(x;\xi;t) = 2C_3^A(t)$$

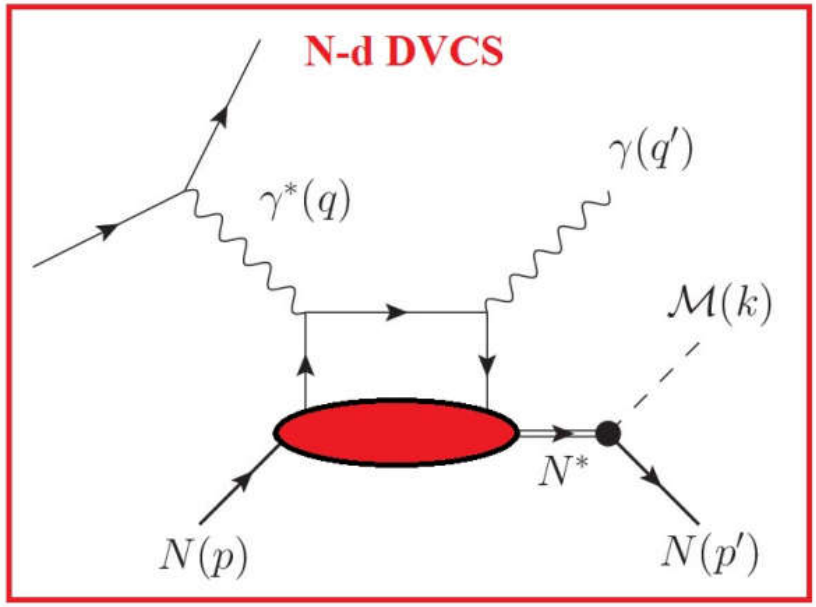
$$\int_{-1}^{1} dx C_4(x;\xi;t) = 2C_4^A(t)$$

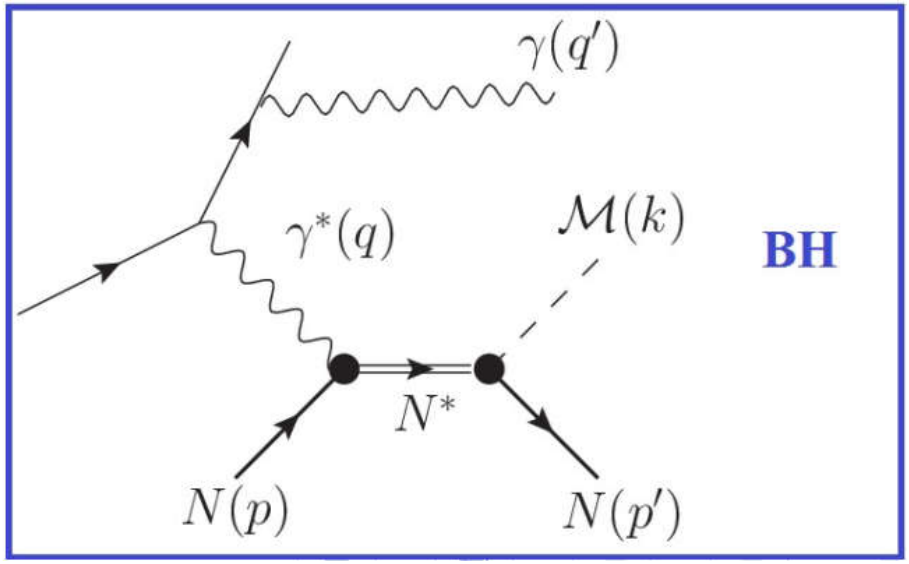
Adler form factors

Experimental Access to Transition GPDs

Experimental access: Non diagonal DVCS process

$$\gamma^* p \to N^* \gamma \to p\ meson\ \gamma$$





process factorizes for

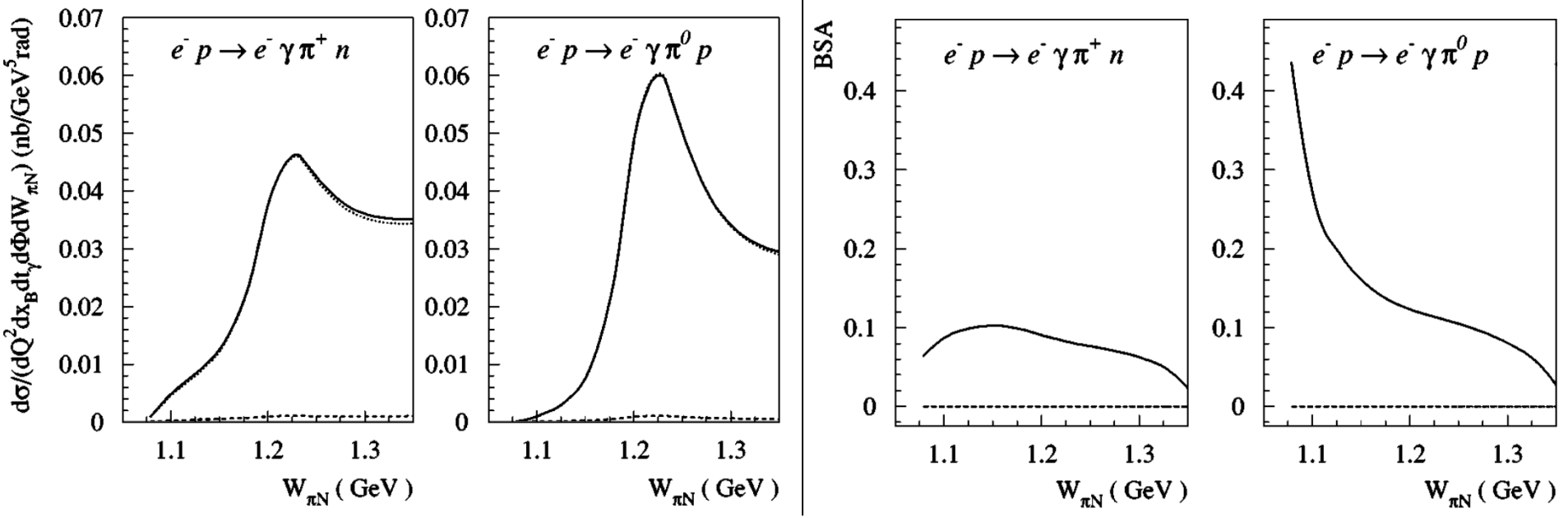
$-q^2$; $(p+q)^2$ – large; $\quad x_B = \dfrac{-q^2}{2p\cdot q}$ – fixed;

$-t = -(p'-p)^2$; $\quad W^2_{\mathcal{M}N} = (p'+k)^2$ of hadronic scale

First Theoretical Description of the Δ Region

P.A.M Guichon, L.Mosse, M. Vanderhaeghen, Phys. Rev. D68 (2003) 034018

cross section | **BSA**



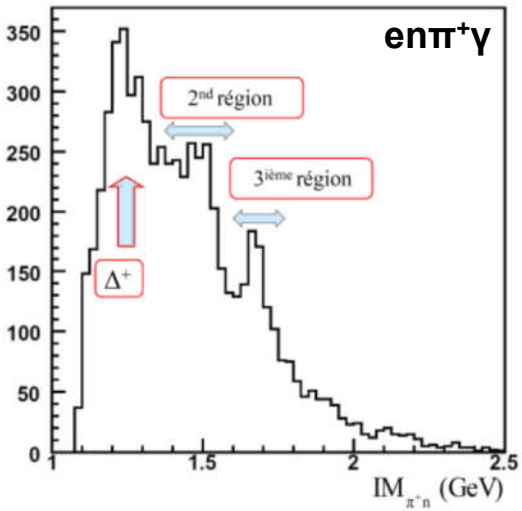
E_e = 6 GeV, Q^2 = 2.5 GeV, x_B = 0.3, t_γ = -0.5 GeV²

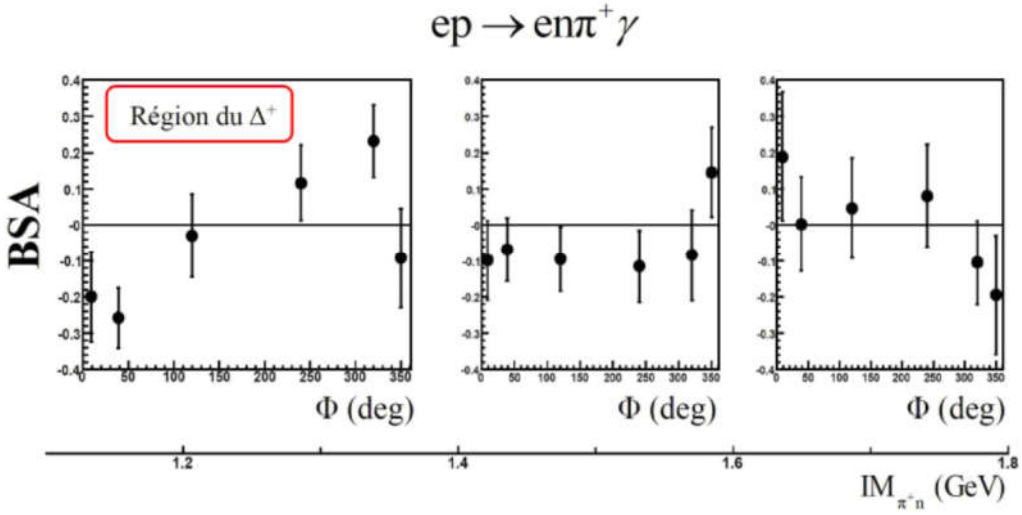
➔ Predictions include a background modell

Previous Studies

Brahim Moreno, PhD thesis UNIVERSITE PARIS-SUD XI (2009)

→ Studies based on CLAS6 data (E_B = 5.4 GeV)



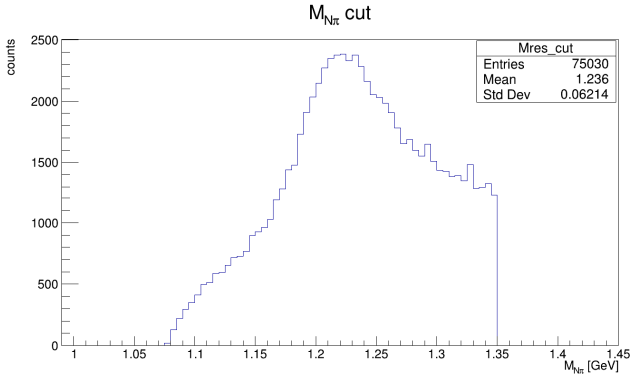


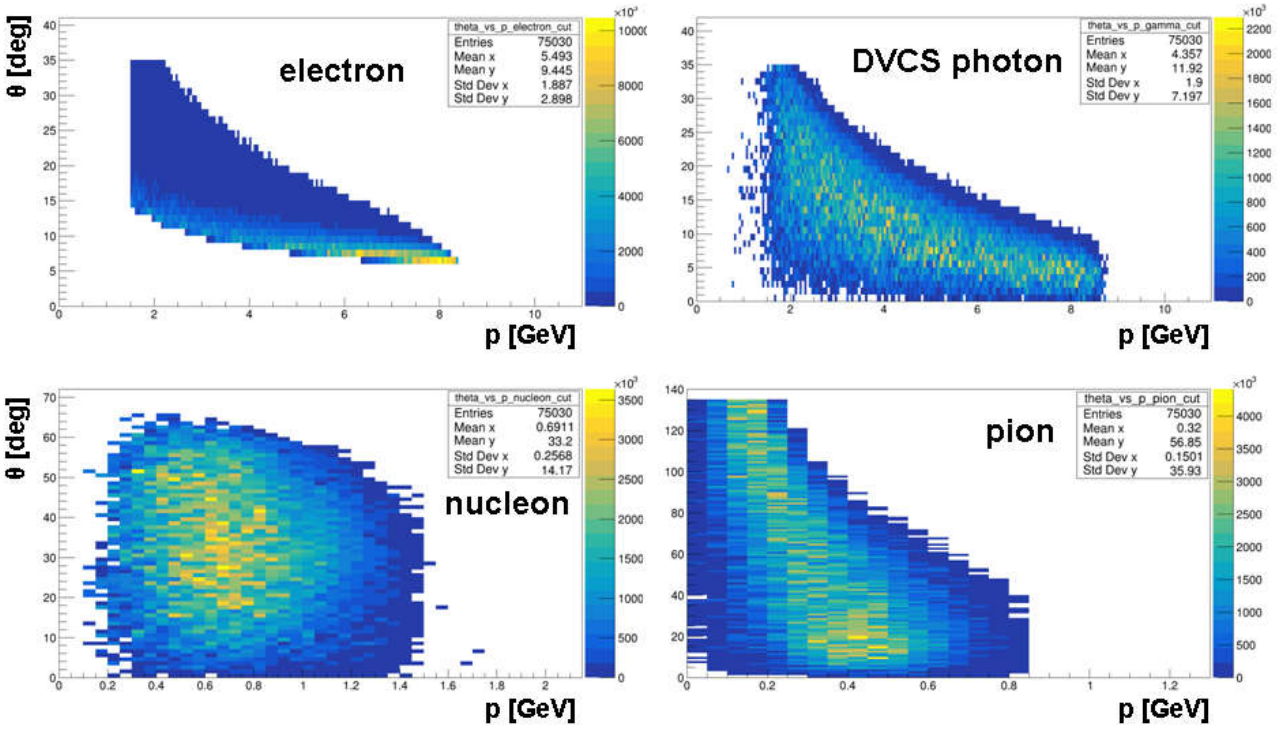
CLAS12:

→ Higher statistics → Higher Q² accessible

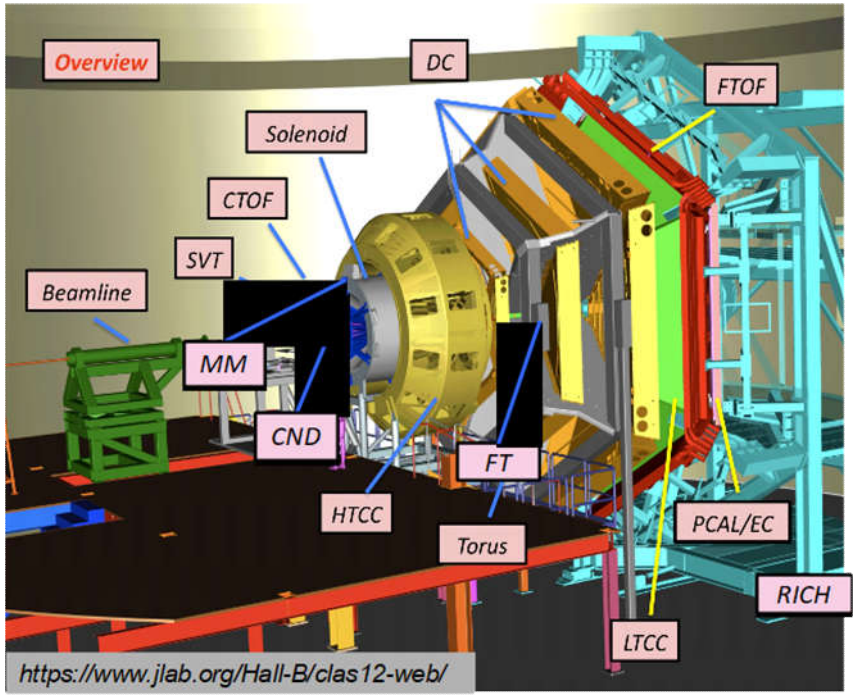
Simulations

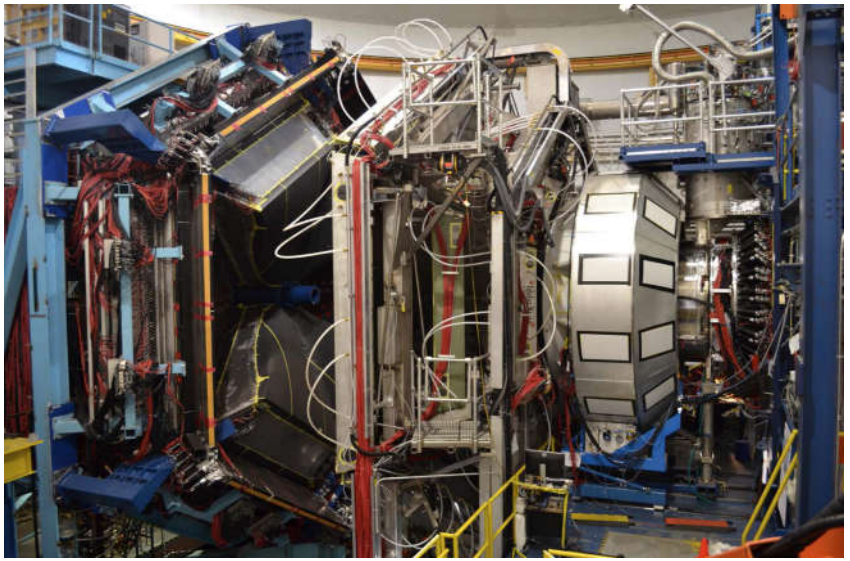
- ➔ A phase space event generator has been developed
- ➔ A realistic resoance mass distribution is implemented for the Δ region
- ➔ The DVCS cross section is added as a weight





CLAS12 Experimental Setup in Hall B





V. Burkert et al., Nucl.Instrum.Meth.A 959 (2020) 163419

➔ Data recorded with CLAS12 during fall of 2018

➔ 10.6 GeV electron beam ➔ 87 % average polarization ➔ liquid H_2 target

➔ Analysed data ~ 20 % of the approved RG-A beam time

Final States and Kinematic Cuts

Two final states have been studied:

$$\gamma^* p \rightarrow N^* \gamma \rightarrow p\pi^0\gamma \rightarrow p\gamma\gamma\gamma$$

$$\gamma^* p \rightarrow N^* \gamma \rightarrow n\pi^+\gamma$$

Kinematic cuts:

W > 2 GeV Q^2 > 1 GeV² y < 0.8 -t < 2 GeV²

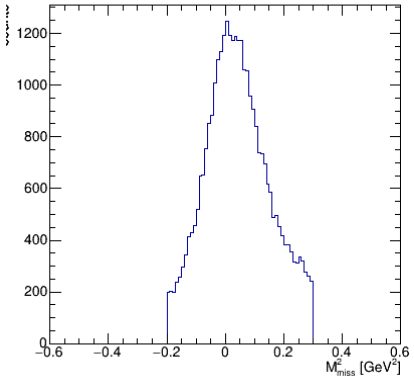
E_{DVCS} > 2 GeV

Exclusivity Distributions

➔ All final state particles are detected

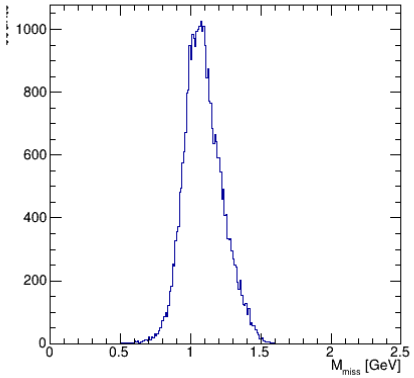
missing DVCS photon

esclusive missing mass2 e n π^+ X



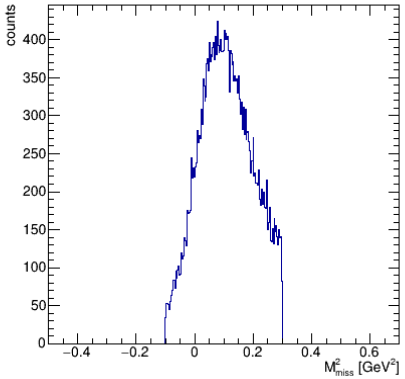
missing neutron

esclusive missing mass e π^+ γ X



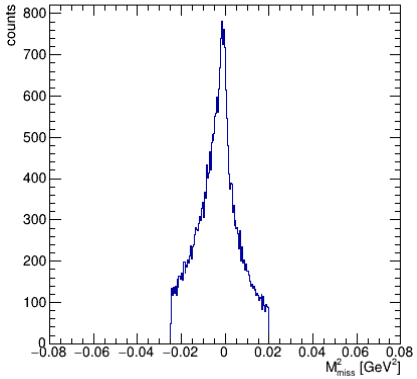
missing pion

esclusive missing mass2 e n γ X



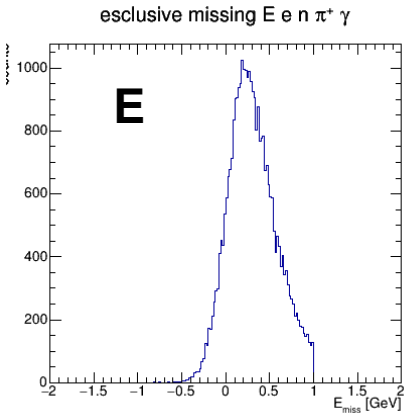
fully exclsuive

esclusive missing mass2 e n π^+ γ

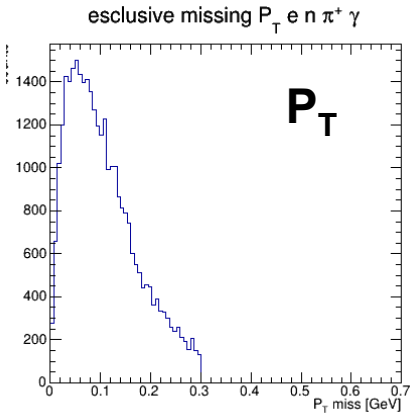


en$\pi^+\gamma$

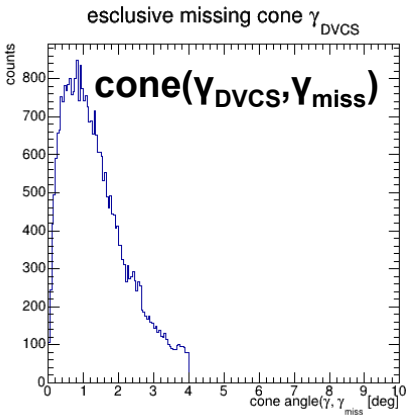
esclusive missing E e n π^+ γ



esclusive missing P_T e n π^+ γ

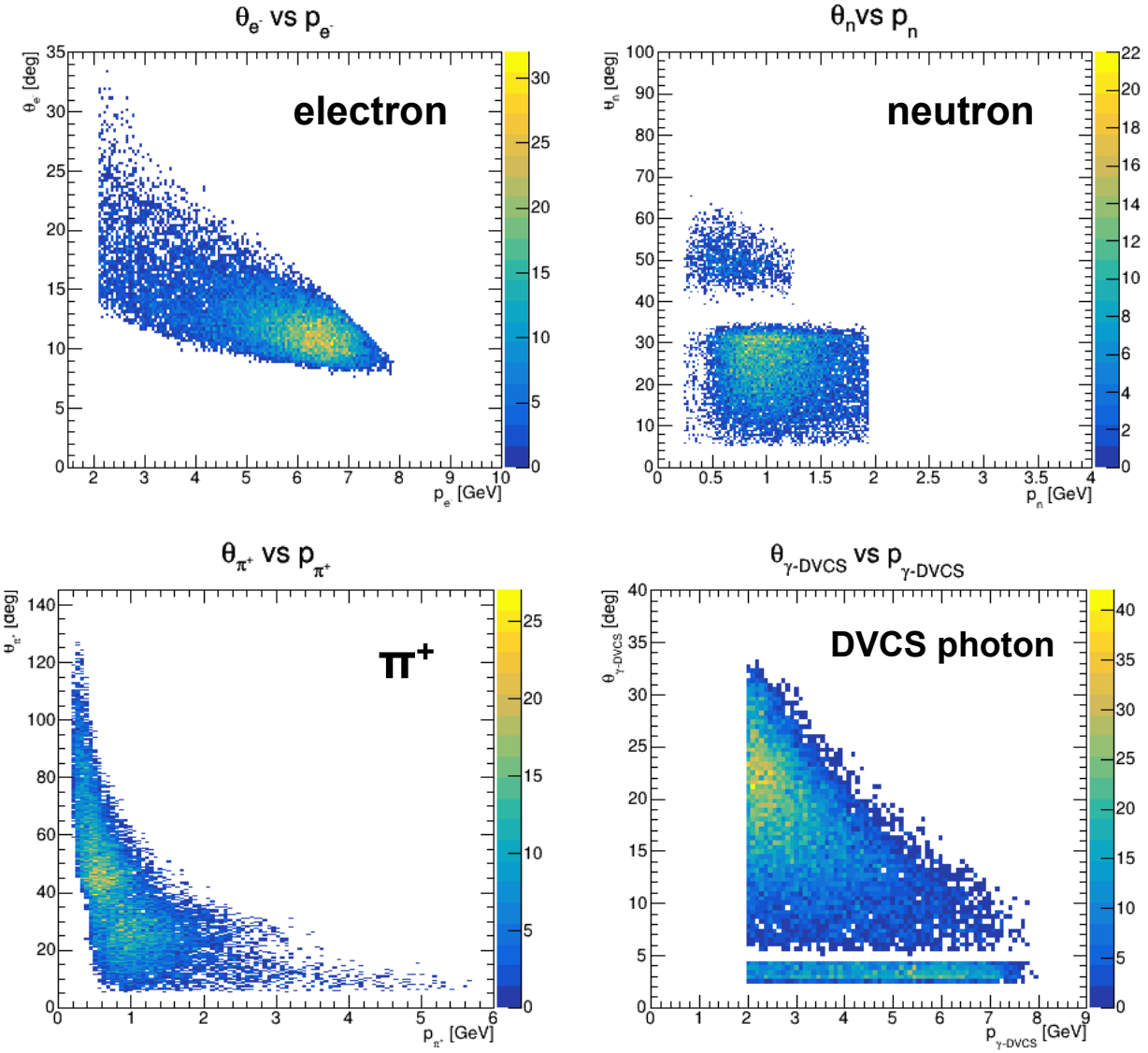


esclusive missing cone γ_{DVCS}

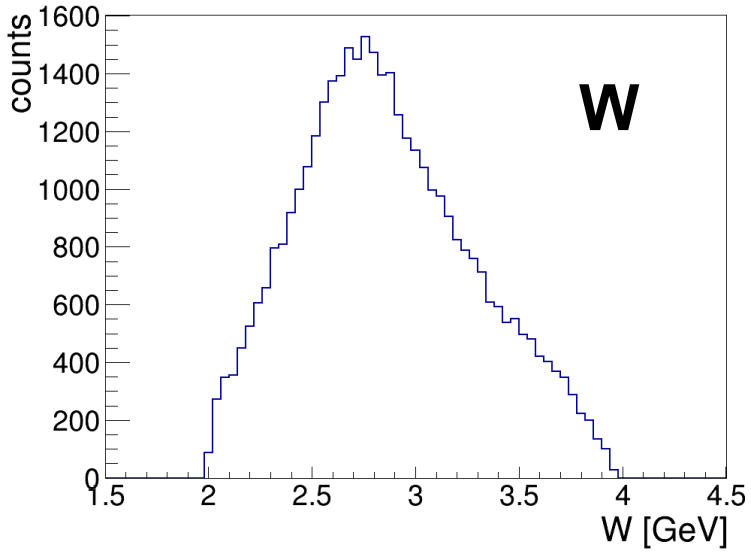


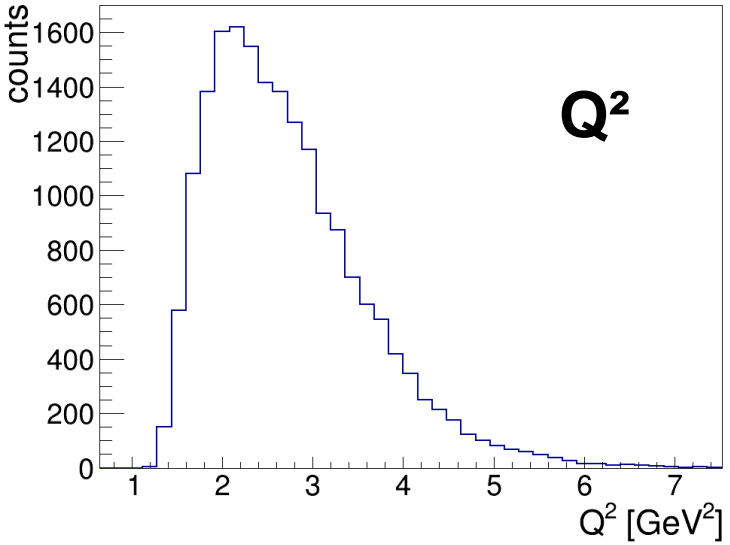
Experimental Particle Distributions

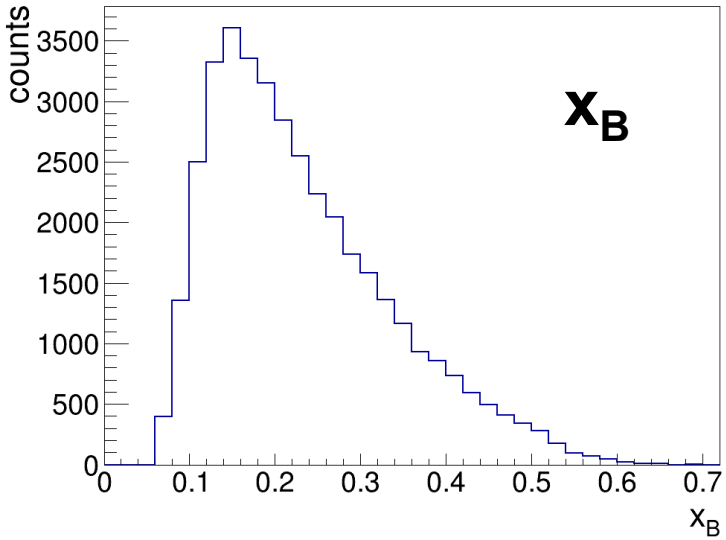
enπ⁺γ

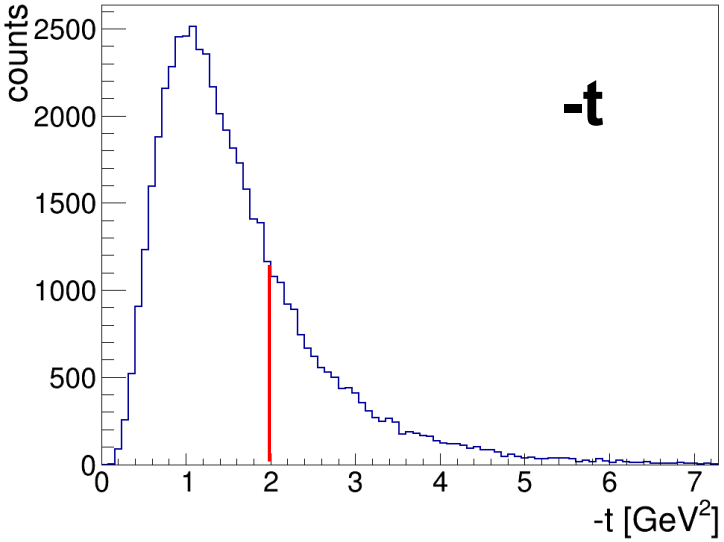


Accessible Kinematic Region



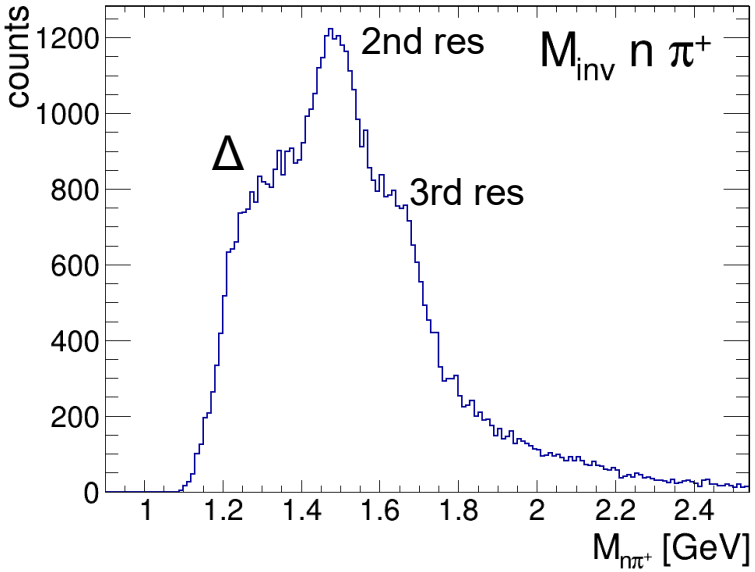




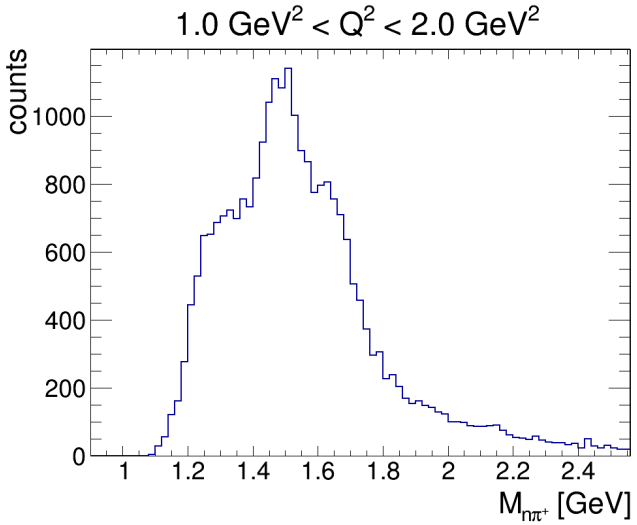


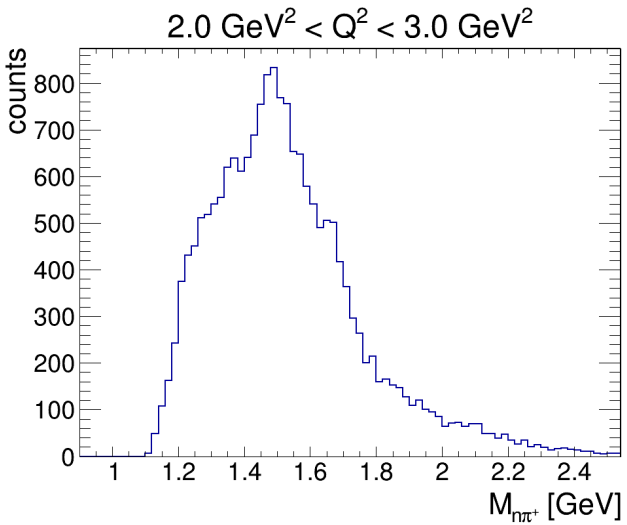
Resonance Mass Spectrum for $N^* \rightarrow n\pi^+$

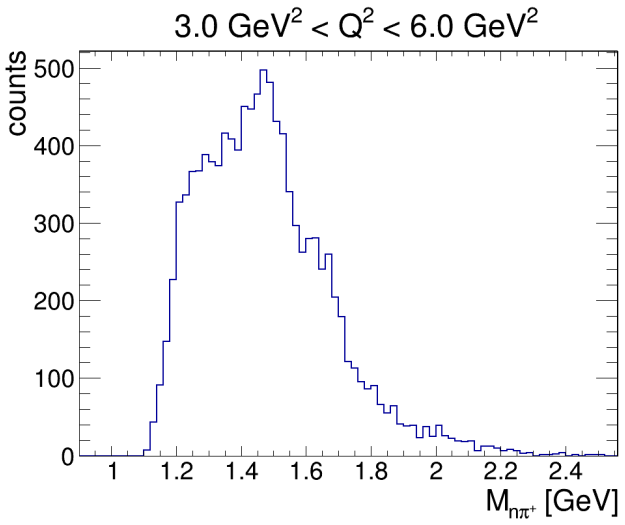
$en\pi^+\gamma$



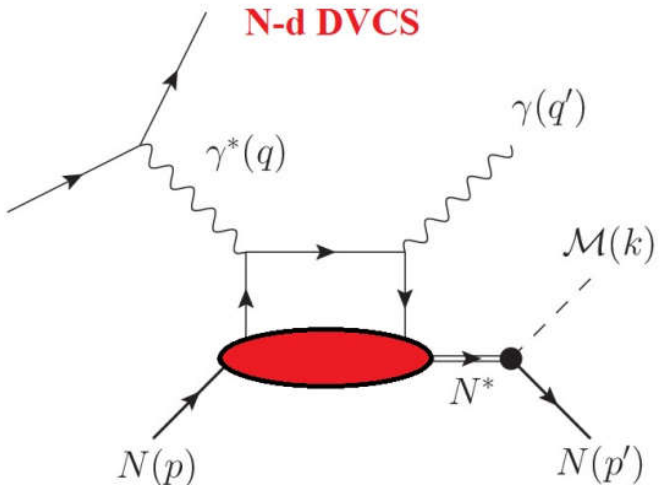
preliminary



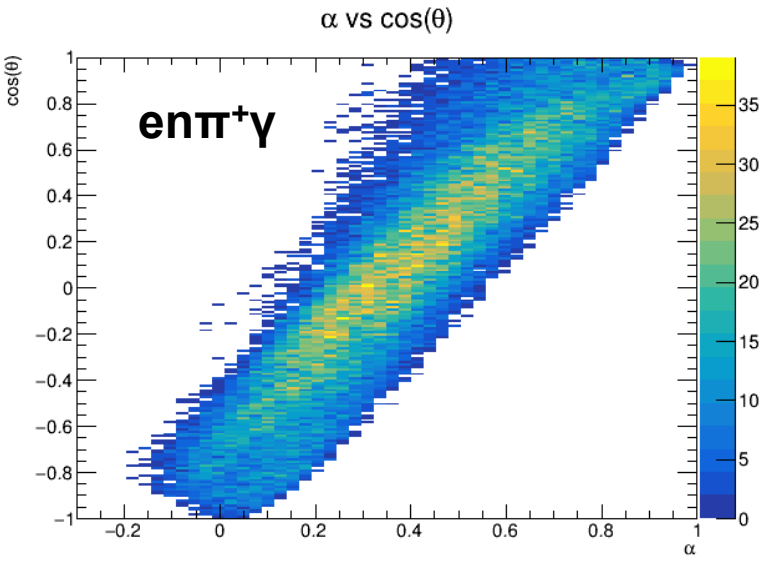


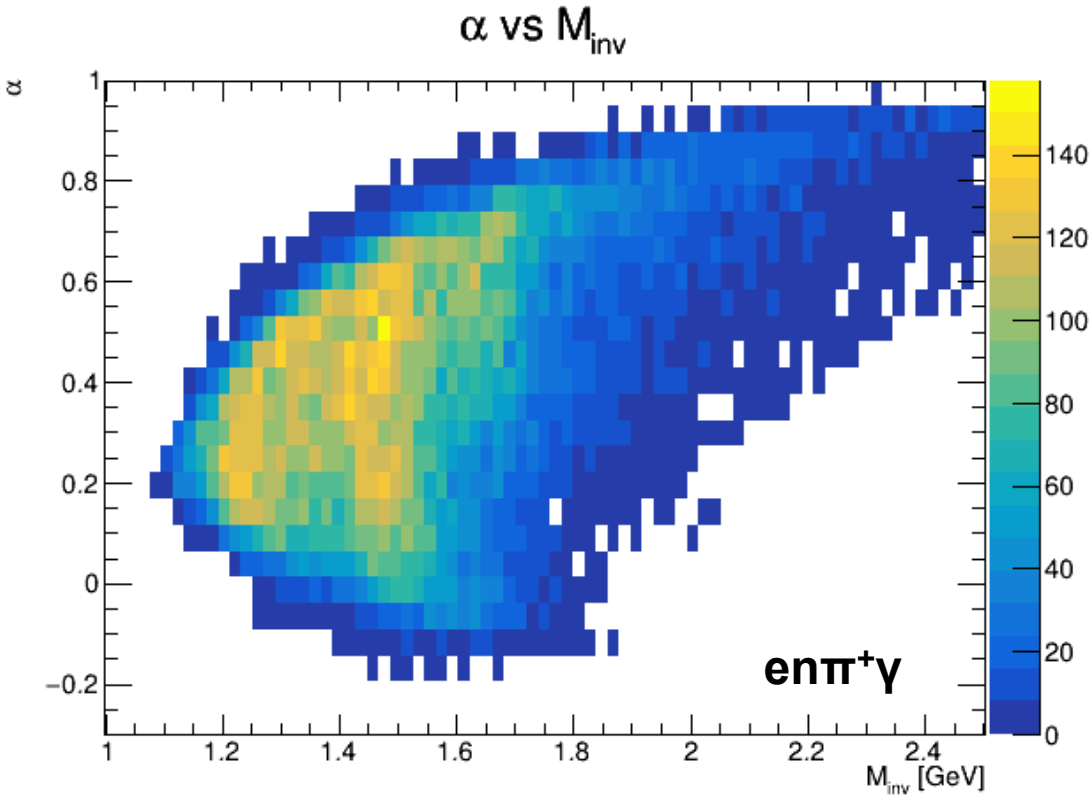


The Pion Longitudinal Momentum Fraction

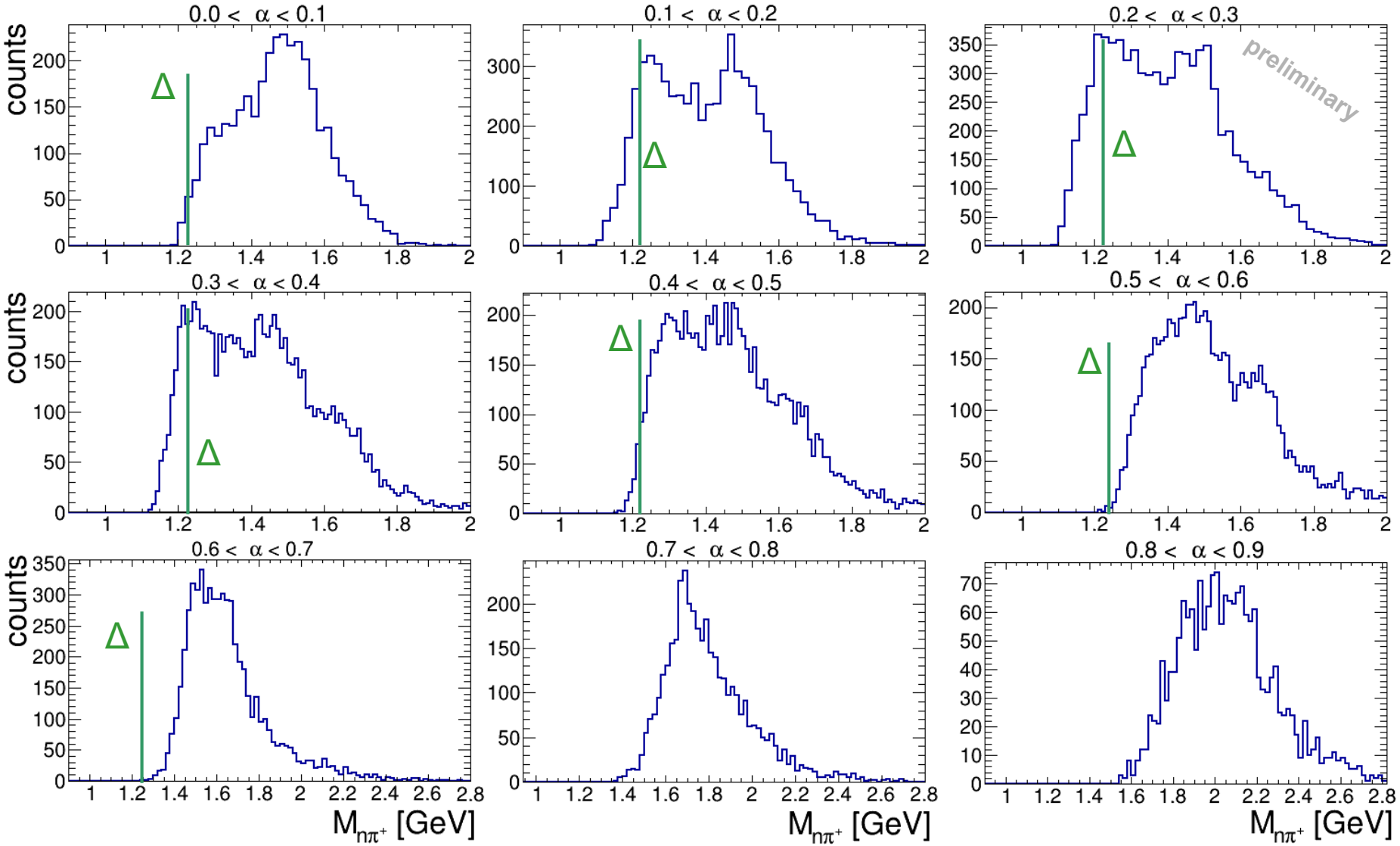


$$\alpha = \frac{(p'+k)\cdot k}{(p'+k)^2}$$



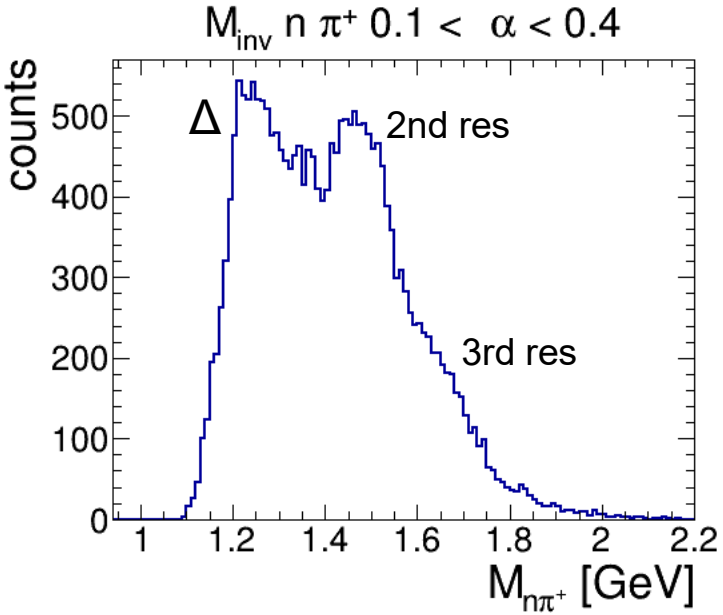


Resonance Mass Spectrum in Bins of α for $N^* \rightarrow n\pi^+$



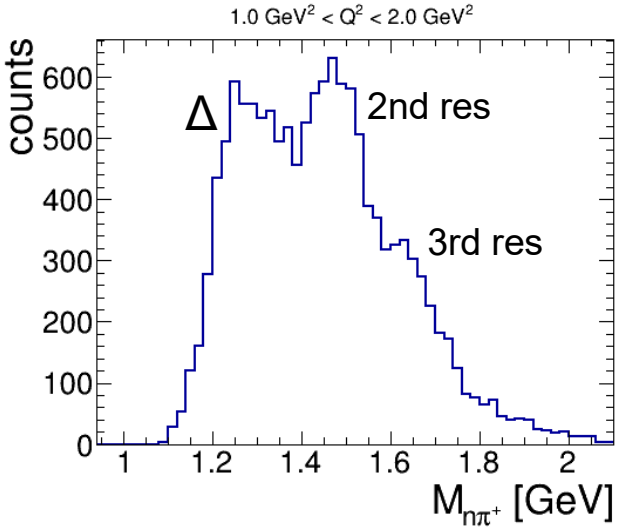
Resonance Mass Spectrum for 0.1 < α < 0.4

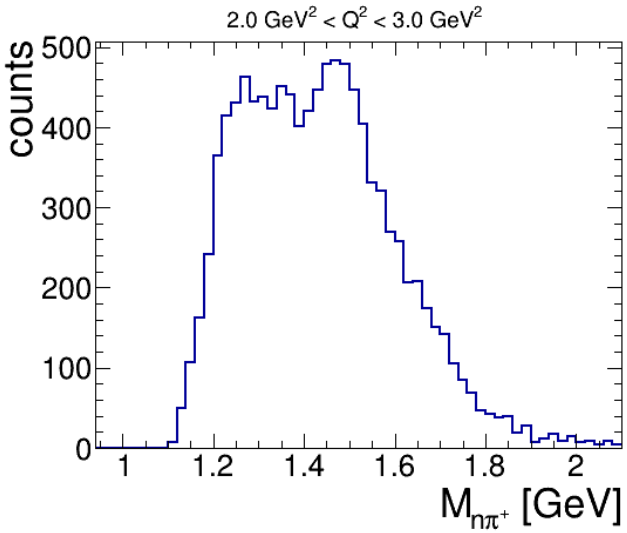
enπ⁺γ

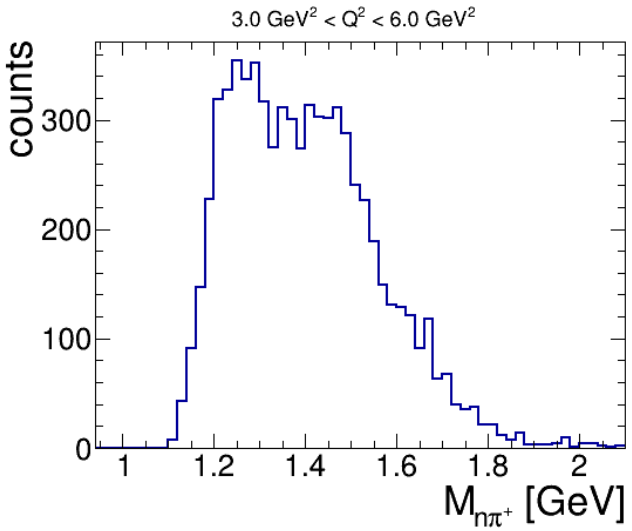


preliminary

Q² dependence:

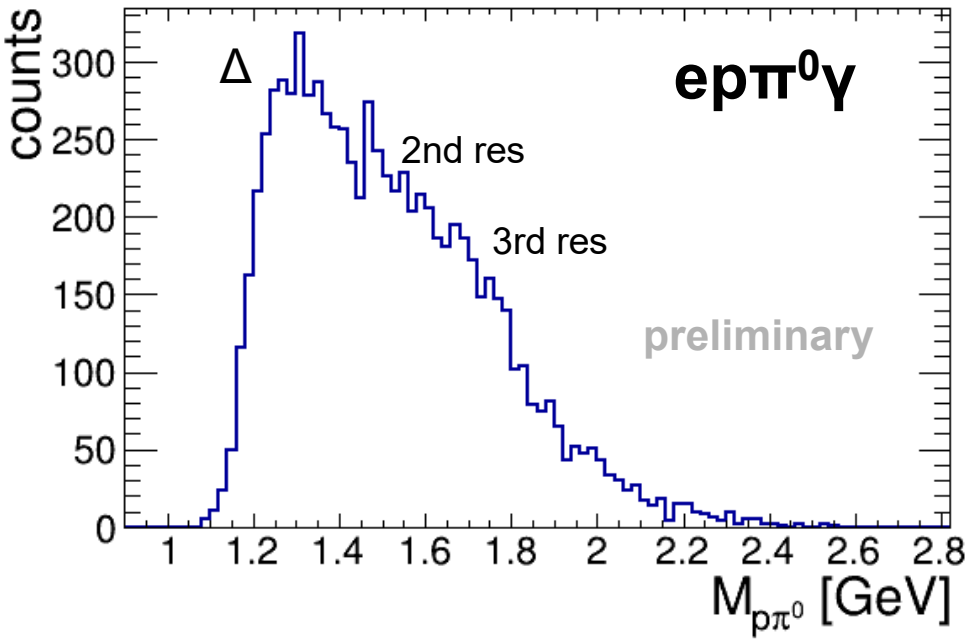




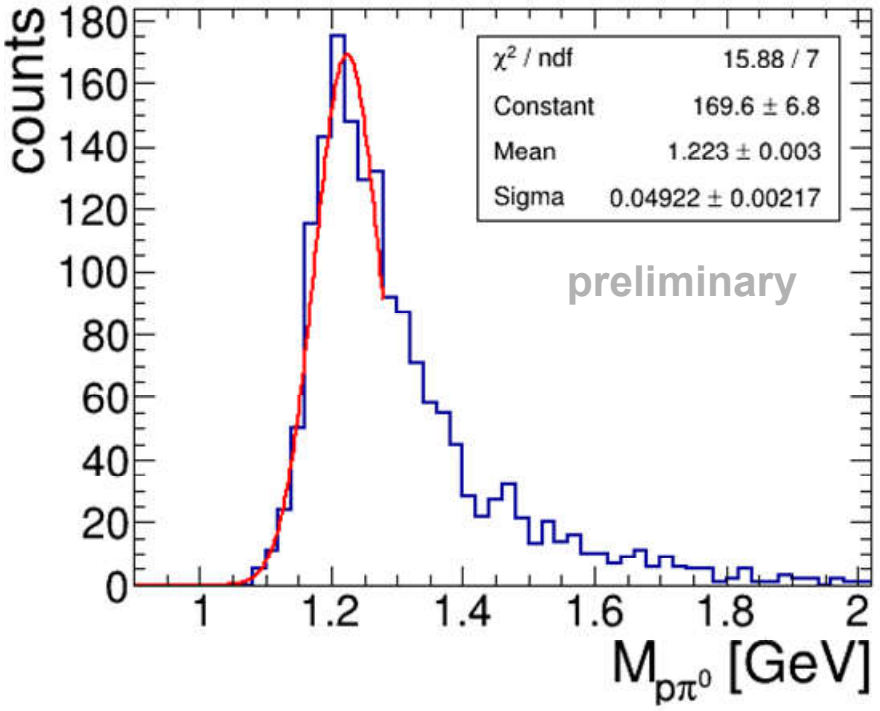


Resonance Mass Spectrum for N* → pπ⁰

full spectrum, no cuts



0.1 < α < 0.4

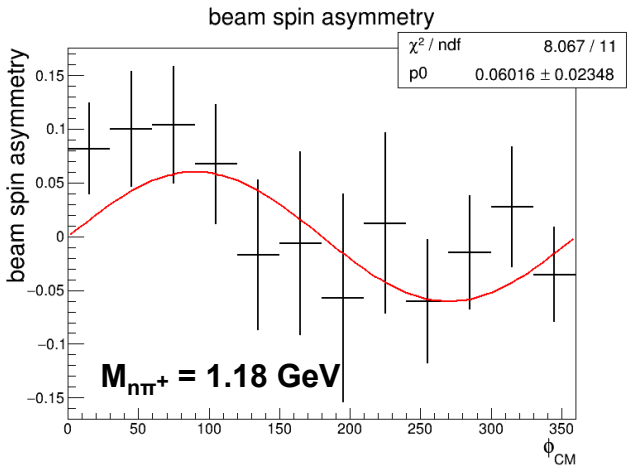


➔ Also for the pπ⁰ final state, a cut on α helps to separate clean Δ events

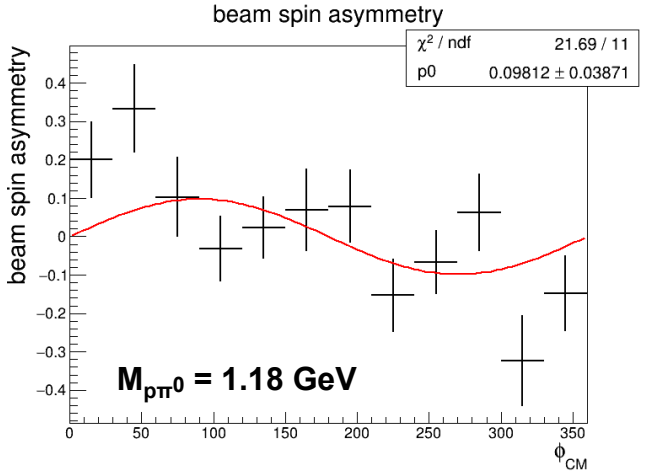
Beam Spin Asymmetries

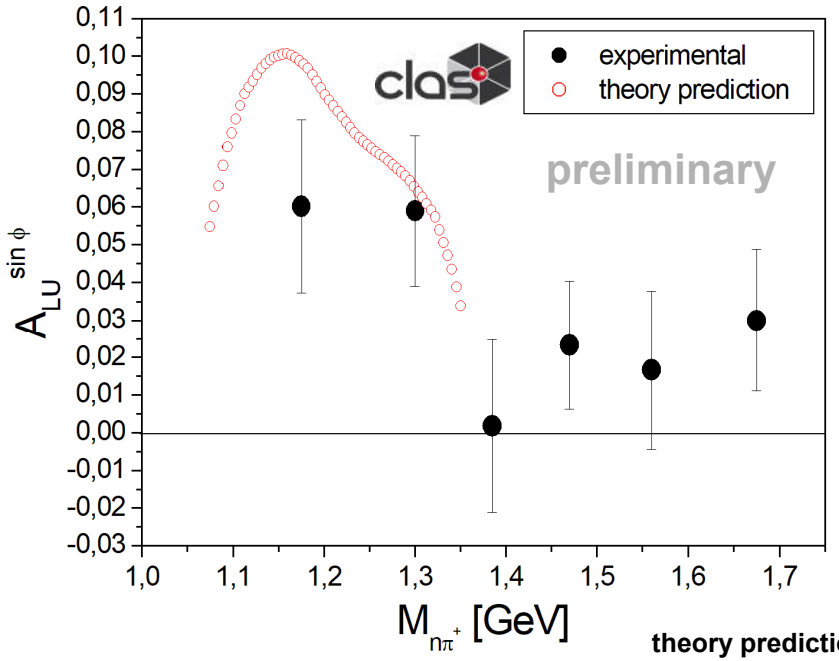
$$A = \frac{1}{P}\frac{N^+ - N^-}{N^+ + N^-} \approx A_{LU}^{\sin\phi}\sin\phi$$

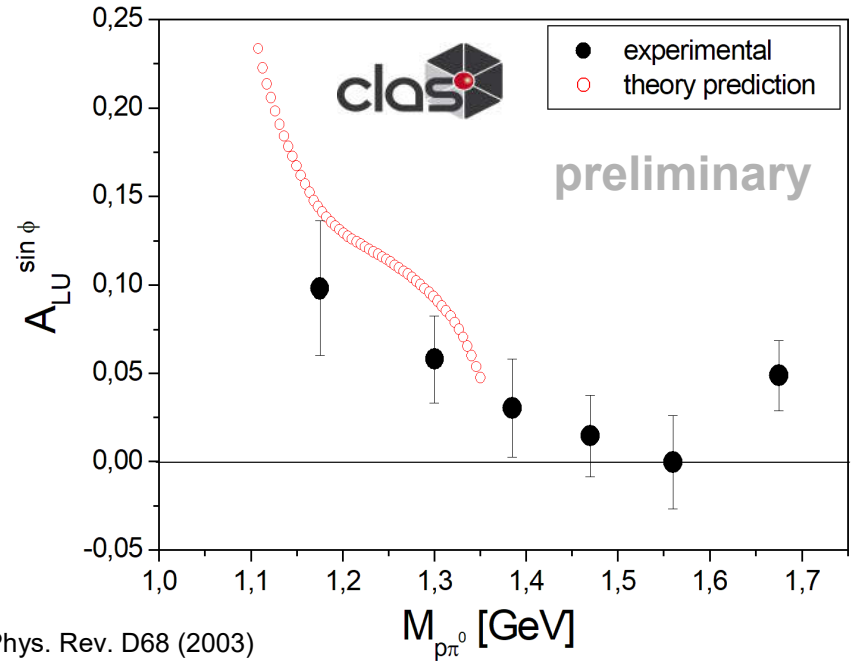
enπ⁺γ



epπ⁰γ







theory prediction: Phys. Rev. D68 (2003)

Conclusion and Outlook

- CLAS12 provides excellent conditions to measure non-diagonal DVCS
- Resonance structures can be identified in the pion – nucleon invariant mass spectrum
- A cut on the pion longitudinal momentum fraction α can help to separate the Δ resonance
- A first BSA extraction provides a qualitative agreement with transition GPD based theory predictions
- Since all parts of CLAS12 are used, a fully optimized setup is required to achieve optimal resolutions
- More statistics will help for BSA exctractions
- **First goal:** Extract / publish observables (BSA) as a function of the resonance mass
- **Second goal:** Separate the resonances, especially the Δ
- A framework for the extraction of transition GPDs will be developed in cooperation with theorists

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